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THE PARALLAX AND PROPER MOTION OF PSR J0030+0451

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ABSTRACT

We report the parallax and proper motion of millisecond pulsar J0030+0451, one of thirteen known isolated millisecond pulsars in the disk of the Galaxy. We obtained more than 6 years of monthly data from the 305 m Arecibo telescope at 430 MHz and 1410 MHz. We measure the parallax of PSR J0030+0451 to be 3.3 ± 0.9 mas, corresponding to a distance of 300 ± 90 pc. The Cordes and Lazio (2002) model of galactic electron distribution yields a dispersion measure derived distance of 317 pc which agrees with our measurement. We place the pulsar's transverse space velocity in the range of 8 to 17 km s^{-1}, making this pulsar one of the slowest known. We perform a brief census of velocities of isolated versus binary millisecond pulsars. We find the velocities of the two populations are indistinguishable. However, the scale height of the binary population is twice that of the isolated population and the luminosity functions of the two populations are different. We suggest that the scale height difference may be an artifact of the luminosity difference.

Subject headings: binaries — pulsars: individual(J0030+0451) — solar neighborhood — solar wind — stars: distances

1. INTRODUCTION

A pulsar parallax can be combined with a measurement of the pulsar's dispersive delay (the Dispersion Measure or DM) to provide an accurate measure of the free electron density along the line of sight (LOS). PSR J0030+0451 is one of fewer than a dozen pulsars to have its parallax measured via timing (Kaspi, Taylor, & Ryba 1994; Camilo, Foster, & Wolszczan 1994; Sandhu et al. 1997; Toscano et al. 1999b; Wolszczan et al. 2000a; Jacoby et al. 2003; Hotan, Bailes, & Ord 2004; Löhmer et al. 2004; Splaver et al. 2005). Another dozen have been measured via VLBI (e.g. see Brisken et al. 2002, Chatterjee et al. 2004, and also this URL[1]). These measurements are important because they give us most of our knowledge about the galactic thermal electron distribution (Cordes & Lazio 2002; Toscano et al. 1999b; Taylor, Manchester, & Lyne 1993).

In addition, PSR J0030+0451 presents a rare evolutionary case as an isolated millisecond pulsar (MSP). In the most popular MSP evolutionary model, MSPs are formed via accretion of matter from a companion star. The incoming matter adds to the pulsar's angular momentum, i.e., the pulsar is "spun up." However, isolated MSPs present a conundrum: they were presumably spun up, yet they are without a companion which would have done so. One possible scenario is that the pulsar has ablated its companion (Ruderman, Shaham, & Tavani 1989).

We expect MSPs to have lower velocities than the regular population, because the kick from the supernova progenitor had to be small enough to leave the binary intact. To produce an isolated MSP, the binary must remain intact during and after the supernova, but then after the spin-up phase the companion must leave the system or be evaporated. Several authors have debated whether isolated MSP velocities are lower, higher, or indistinguishable from those of the general population of MSPs. McLaughlin et al. (2004) suggest we might expect isolated MSPs to have higher velocities. They argue that if isolated MSPs are formed by ablation, we would expect them to form from the tighter binaries which are more susceptible to ablation. The correlation between tight binaries and higher velocities is suggested by Tauris & Bailes (1996). McLaughlin et al. (2004) present the argument for faster velocities for isolated MSPs as a counter-

[1] http://www.astro.cornell.edu/∼shami/psrvlb/parallax.html

point to their timing proper motion and scintillation measurements which suggest the opposite, as do the measurements of Johnston, Nicastro, & Koribalski (1998) and Toscano et al. (1999b). Hobbs et al. (2005), however, find the velocities of the populations to be indistinguishable. We present a measurement of the transverse velocity of PSR J0030+0451 which is unusually small, even compared to the isolated MSP population. We reconsider the question of the velocity of isolated MSPs as compared to the binary MSP population.

Owing to its small timing residual, $\sim$1 μs, PSR J0030+0451 is a good candidate for membership in the Pulsar Timing Array (PTA), which is a collection of pulsars that will be used for detecting gravitational radiation (Jaffe & Backer 2003; Jenet et al. 2004). For this reason, continued refinement of the timing model of PSR J0030+0451 is important. In fact, the PTA, as it is conceived, is an interferometer, so a variety of baselines will be important to its operation. PSR J0030+0451 may be particularly useful in this regard because it has large angular separation from PSRs B1855+09, J1713+07 and J0437-4715, which are among the most stable and precise pulsars (Kaspi, Taylor, & Ryba 1994; van Straten et al. 2001; Lommen 2001).

In §2 we present a significant refinement to the timing model previously published (Lommen et al. 2000). We discuss our measurements of parallax and proper motion in §3. We include the effects of the solar wind in our analysis, which we discuss in §4. In §5,§6, and §7 we discuss the space velocity of J0030+0451, corrections to its measured period derivative, and the implications of its measured distance for the local interstellar medium (LISM). In §8 we summarize our conclusions.

2. ARECIBO OBSERVATION AND DATA REDUCTION

We have conducted timing observations over a 6.5 year period, from 1997 December to 2004 July, at the Arecibo Observatory, using the Arecibo-Berkeley Pulsar Processor (ABPP) and the Princeton Mark IV system. Details of ABPP signal processing can be found in Lommen et al. (2000), where the first three years of these data are presented. Details of Mark IV signal processing can be found in Stairs et al. (2000).

Over the course of each observation, incoming signals from two orthogonal polarizations were coherently dedispersed, squared to obtain power measurements, and folded modulo the pulse period for intervals of three minutes. Opposite polarizations were summed, using absolute flux calibrations of the receivers whenever possible or, when absolute flux calibration was not available, using the system temperature of the pulsed noise source as published by telescope operations.

Pulse times of arrival (TOAs) were derived from the calibrated three minute integrations using conventional algorithms. The TOAs from a given frequency and instrument on a given day were averaged into a single effective TOA for that day, the uncertainty of which was estimated from the spread of the individual three-minute TOAs.

We performed a weighted fit to the averaged TOAs using TEMPO[2]. We used ecliptic coordinates to minimize covariance between the two components of the position and proper motion measurements. This is usually necessary when the ecliptic latitude is low (1.44° in our case). Table 1 shows updated spin, astrometric, and other parameters for PSR J0030+0451. The root mean squared (rms) of the timing residuals quoted in Table 1, is calculated using TOAs from profiles averaged over 30 minutes. We estimated uncertainties in all the fitted parameters by doubling errors given by TEMPO, an ad hoc procedure that attempts to account for timing noise and other possible systematic errors. The quoted uncertainty in parallax also includes a term added in quadrature (0.3 mas) due to the solar wind (see §4). Residual arrival times after subtracting the best fit are shown in Figure 1.

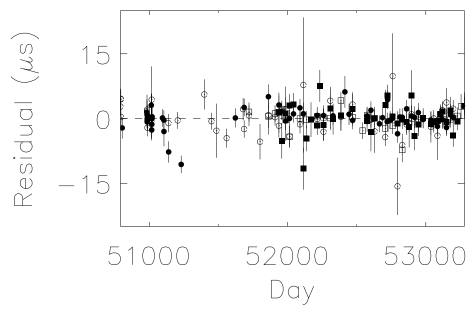

FIG. 1.— Residual vs day for the model presented in Table 1. Circles are ABPP data. Squares are Mark IV data. Filled points are 1410 MHz. Open points are 430 MHz data.

We examined timing solutions in which DM was allowed to vary over time, and we found that they did not significantly improve the fit quality or change the timing model parameters. However, it is interesting to compare our upper limit on $\dot{\mathrm{DM}}$, the time derivative of DM, to the correlation between DM and $\dot{\mathrm{DM}}$ measured by Backer et al. (1993). When $\dot{\mathrm{DM}}$ is included in the timing model, its best-fit value is $(1.9 \pm 1.8) \times 10^{-5}$ cm^{-3}pc yr^{-1}, which implies an upper limit (with 95% confidence) of 5.5×10^{-5} cm^{-3}pc yr^{-1}. This value is smaller than expected according to Backer et al. (1993) by about a factor of 5. If more small-DM small-$\dot{\mathrm{DM}}$ pulsars are found it might suggest that $\dot{\mathrm{DM}}$ is a stronger function of DM than we would expect for wedgelike thermal plasma perturbations distributed randomly along the LOS.

3. PROPER MOTION AND PARALLAX

Evidence for a significant parallax measurement is shown in Figure 2, which compares residuals of the pulse arrival times with and without parallax incorporated into the timing model. The figure shows averaged timing residuals versus day number binned in increments of 18 days and folded over a half-year period to provide the best visibility for the parallax signature. The data have been fit for proper motion but not for parallax in the left part of Figure 2. Data on the right have been fit for both proper motion and for parallax. We have superimposed the best-fit parallax curve onto the pre-fit data. On close examination of Figure 2, there is a subtle difference in the positions of the data points relative to the fit curve (left plot) and the horizontal axis (right plot). This is not an unexpected result of (a) a global fit to all the parameters with and without parallax and (b) the post-fit binning.

Our best-fit value for parallax, $\pi = 3.3 \pm 0.9$ mas, includes both measurement uncertainty of 0.88 mas and systematic uncertainty due to the solar wind model, 0.3 mas, which will be discussed in the following section.

We measure a proper motion of -5.74 ± 0.09 mas yr^{-1} in the plane of the ecliptic. Proper motion out of the ecliptic plane is naturally difficult to measure given the pulsar's position, a problem which was compounded by its high covariance with

[2] See http://pulsar.princeton.edu/tempo

TABLE 1
PARAMETERS FOR PULSAR J0030+0451

Parameter	Value[a]
Ecliptic longitude (deg)	8.91036695(6)
Ecliptic latitude (deg)	1.445692(3)
Period (s)	0.00486545320829334(3)
Period derivative ($s\,s^{-1}$)	$1.0162(1)\times10^{-20}$
Proper motion in ecliptic longitude (mas yr^{-1})	–5.74(9)
Absolute value of proper motion in ecliptic latitude (mas yr^{-1})	< 10
Dispersion measure (pc cm^{-3})	4.3328(2)
Epoch (MJD)	52035
Solar n_o (e^- cm^{-3})	6.9(2.1)
Solar $\dot{n}_o$ ($e^- cm^{-3} yr^{-1}$)	0.0(3)
Number of epochs of data [b]	56
Timing data span (MJD)	50,790 – 53,280
Right ascension(J2000)	00 30 27.4308(6)
Declination(J2000)	+04 51 39.72(1)
Galactic longitude (deg)	113.141135(1)
Galactic latitude (deg)	–57.611237(3)
DM derived distance (pc)[c]	317(25)
Characteristic age (yr)	7.8×10^9
Magnetic field strength (G)[d]	2.7×10^8
Column electron density along LOS (e^- cm^{-3})	0.014(2)
Parallax (mas)	3.3(9)
Parallax derived distance (pc)	300(90)
Magnitude of transverse velocity (km s^{-1})	8–17
RMS residual at 430 MHz (μs, ABPP/MarkIV)	2.3/1.0
RMS residual at 1410 MHz (μs, ABPP/MarkIV)	2.2/2.2

[a]Uncertainties in parentheses refer to the last digit quoted. Note that a n_0 of 6.9 cm^{-3} was assumed in all fits.
[b]We define "epoch" as data separated by 2 weeks or more.
[c]Model from NE2001.
[d]$B_0 = 3.2 \times 10^{19}$ $G[P(s)\dot{P}_0]^{1/2}$.

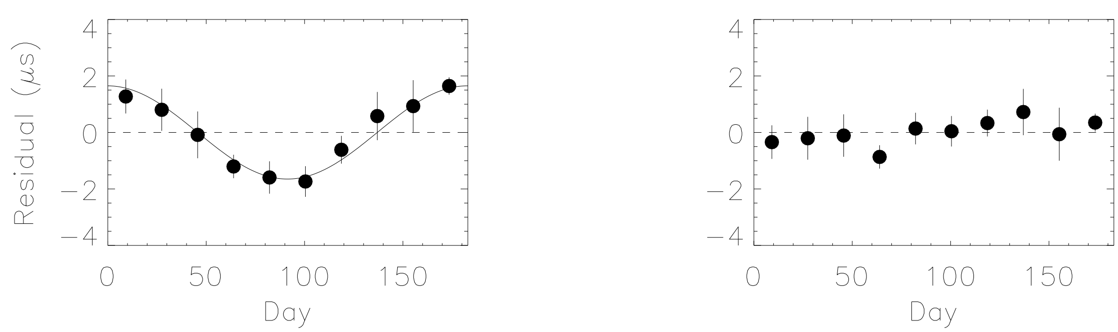

FIG. 2.— Timing residuals for J0030+0451 folded over a period of a half year and binned every 18 days. Left: Residuals with no parallax fit. Right: Residuals after removal of parallax of 3.3 mas from the data in the left hand panel. The curve that represents the 3.3 mas parallax is shown in the left hand panel. Day 0 is when the Earth-Sun-pulsar angle is 90°.

variations in dispersion measure. We quote a conservative upper limit on the magnitude of the out-of-plane proper motion of 10 mas yr^{-1}.

We can combine our distance measurement with our proper motion measurements to yield the pulsar's velocity. We obtain a velocity of -8.3 ± 0.1 km s^{-1} in the plane of the ecliptic and an upper limit of 14.4 km s^{-1} out of the plane of the ecliptic. Thus, the pulsar's transverse velocity lies between 8 and 17 km s^{-1}. This confirms the value presented by Nicastro et al. (2001), 9 ± 6 km s^{-1}, which they found using scintillation measurements.

The measured proper motion of PSR J0030+0451 results not just from its motion relative to its local standard of rest (LSR), but also from the difference between its LSR and the LSR of the sun and from the solar motion. After considering these effects (see §5 for details), we calculate its transverse velocity relative to its LSR to be between 4 and 20 km s^{-1}.

This is one of the slowest transverse velocities measured for any pulsar. Young pulsars (those which have not been spun up) have a mean velocity of 265 km s^{-1} (Hobbs et al. 2005), a factor of three times faster than MSPs (§5; see also Hobbs et al. 2005; Cordes & Chernoff 1997; Nice & Taylor 1995). PSR J0030+0451 is, in fact, only one tenth as fast as the average MSP (§5).

4. THE SOLAR SYSTEM ELECTRON DENSITY

PSR J0030+0451 is roughly in the ecliptic plane (ecliptic latitude is 1.44°) where the solar system provides additional dispersion caused by the charged particles of the solar wind. Issautier et al. (2001) show that the solar electron density, n_e, can be modeled as n_0/r^2, where r is the radial distance to the sun in astronomical units, and n_0 is roughly 10 cm^{-3} (Splaver et al. 2005; Issautier et al. 2001). This simple model is the default in TEMPO. Maintaining the $1/r^2$ dependence, we searched χ^2 space for the best value of n_0, which we found to be $6.9 \pm 2.1\,\mathrm{cm}^{-3}$.

Reducing n_0 from 9.0 to 6.9 cm^{-3} reduces the fitted parallax by about 0.3 mas which increases the distance by about 30 pc. These two parameters are covariant because the model of the solar wind yields an annual pattern of pulse delays with a strong cusp when the pulsar is behind the sun with respect to the earth. A Fourier decomposition of this delay pattern yields significant terms with annual periodicity (covariant with pulsar position), semi-annual periodicity (covariant with parallax), as well as higher order terms. The additional 0.3 mas uncertainty in parallax due to the solar wind was added in quadrature to the doubled TEMPO error.

Note that in the case of PSR J1713+0747, another ecliptic plane MSP, Splaver et al. (2005) found it necessary to eliminate data within 30° of the sun. In our case we did not find that this significantly improved the fit, nor did it substantially change any fitted parameters.

We wondered if it would be possible to measure a change in the solar wind on its 11-year cycle. Using TEMPO we mapped χ^2 space in the range of -10 cm^{-3} yr^{-1} $< \dot{n}_o <$ 10 cm^{-3} yr^{-1} but found that the minimum in χ^2 occurred at an essentially null value of $0.0 \pm 0.3\,\mathrm{cm}^{-3}\,\mathrm{yr}^{-1}$, indicating that the change is currently beyond our measurement capability.

5. VELOCITIES OF MSPS: ISOLATED VS BINARY

Hobbs et al. (2005) presents an extensive study of the velocities of various sub-groups of pulsars, including isolated and binary recycled pulsars. They find that isolated recycled pulsars are not significantly slower ($77 \pm 16\,\mathrm{km\,s^{-1}}$) than binary recycled pulsars ($89 \pm 15\,\mathrm{km\ s^{-1}}$). When the velocity of PSR J0030+0451 (using 9 km s^{-1}) is added to the sample the average velocity of isolated recycled pulsars becomes $68 \pm 16\,\mathrm{km\ s^{-1}}$, which is still not significantly different from the average of the binary recycled pulsars. In contrast, both Johnston, Nicastro, & Koribalski (1998) and Toscano et al. (1999b) previously claimed to see evidence that isolated MSPs are slower than binary MSPs. However, when one uses a more recent Galactic electron density model to estimate the distances to the pulsars (Cordes & Lazio 2002), the discrepancy disappears. This is a potent reminder that a distance model has a significant effect on conclusions drawn from it. McLaughlin et al. (2004) also find the isolated MSP population to have a slightly lower average velocity (70 km s^{-1}) as compared to the binary population. They caution against drawing conclusions from velocity data which are based on imprecise distances.

We performed an analysis of the velocity data that is slightly different from the analysis done by Hobbs et al. (2005) with similar results. We defined an MSP to be any pulsar with period $P < 0.01$ s, which provides a narrower sample than that used by Hobbs et al. (2005) who defined MSPs to be any pulsar with period $P < 0.1$ s and period derivative $\dot{P} < 10^{-17}$. Our criterion means that the binary pulsars in our sample nearly all have helium white dwarf companions, whereas Hobbs et al. used binaries with a mix of companion types.

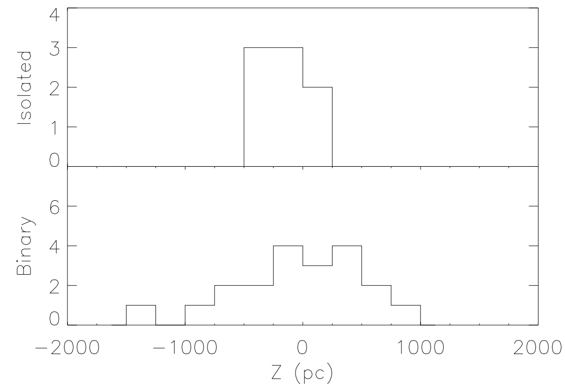

FIG. 3.— Histograms of height above the galactic plane for the isolated MSP population (upper) and the binary MSP population (lower).

The 29 MSPs in the Galactic Disk with measured proper motions are shown in Table 2. PSR J1730-2304, which has no measured declination proper motion, has been included in the table for completeness but has not been included in any of the following calculations. We corrected each pulsar's velocity to its LSR as follows. We used the measured proper motion and distance to calculate a three dimensional vector representing the (two dimensional) transverse motion of the pulsar in the reference frame of the Sun. We then removed the solar motion and rotated the resulting vector from the LSR of the sun to the LSR of the pulsar. Finally, we recovered those two components of the vector which are perpendicular to the line of sight. This computation required selecting a value for the unknown LOS velocity of the pulsar; we chose a value appropriate for a star at rest in the pulsar's LSR.

This corrected velocity is listed in the second to last column of Table 3. The average corrected velocity of the isolated MSPs is 86 ± 19 km s^{-1} whereas the average corrected velocity of all the binary MSPs is 91 ± 28 km s^{-1}. (The uncorrected averages are 79 and 90 km s^{-1} respectively). If one allows the sample to include only those proper motions which have been measured to better than 2σ the average corrected velocities are $86 \pm 19\,\mathrm{km\,s^{-1}}$ and 99 ± 33 km s^{-1} respectively. (Uncorrected averages are 79 and 99 km s^{-1}.) In each case the isolated MSP population is indistinguishable from the binary MSP population. The 2σ cutoff in velocity introduces a selection of higher velocity pulsars. Thus, the average velocities are higher in that case.

An alternative statistic for evaluating the dynamics of pulsar populations is the distribution of heights above or below the galactic plane, z. For the pulsars listed, one finds that the standard deviation from zero for the binary MSP population is twice that of the isolated MSP population: 570 ± 90 pc vs 280 ± 65 pc. Figure 3 shows a histogram of z for each population. The isolated MSP population is represented in the upper half of the figure, the binary MSP population in the lower half.

Figure 3 shows that the known isolated MSPs are closer to the Plane than are the known binary MSPs. This could be either a reflection of differences in the intrinsic spatial distributions of the two types of MSPs, or a selection effect. A smaller intrinsic spread in scale heights for isolated MSPs is only possible if that population also has a smaller intrinsic velocity distribution, so that the objects do not travel as far from the Plane

TABLE 2
VELOCITIES OF MILLISECOND PULSARS IN THE GALACTIC DISK

Pulsar	μ_α (mas yr^{-1})	μ_δ (mas yr^{-1})	Distance (pc)	v_t (km s^{-1})	Reference
		Isolated MSPs			
J0030+0451	$\mu_\lambda = -5.84 \pm 0.09$	$\lvert\mu_\beta\rvert < 10$	310[p]	<20	This work
J0711–6830	–15.7 ± 0.5	15.3 ± 0.6	860[n]	113	Toscano et al. (1999a)
J1024–0719	–41 ± 2	–70 ± 3	200[o]	70	Toscano et al. (1999a)
J1730–2304	20.5 ± 0.4	···	510[n]	>50	Toscano et al. (1999a)
J1744–1134	18.64 ± 0.08	–10.3 ± 0.5	360[p]	31	Toscano et al. (1999a)
B1937+21	–0.130 ± 0.008	–0.469 ± 0.009	3600[n]	87	Kaspi, Taylor, & Ryba (1994)
J1944+0907	12.0 ± 0.7	–18 ± 3	1800[n]	173	Champion et al. (2005)
J2124–3358	–14 ± 1	–47 ± 1	270[n]	48	Toscano et al. (1999a)
J2322+2057	–17 ± 2	–18 ± 3	790[n]	79	Nice & Taylor (1995)
		Binary MSPs			
J0437–4715	121.438 ± 0.006	–71.438 ± 0.007	140[p]	84	van Straten et al. (2001)
J0613–0200	2.0 ± 0.4	–7 ± 1	1700[n]	60	Toscano et al. (1999a)
J0751+1807	$\mu_\lambda = 0.35 \pm 0.03$	$\mu_\beta = -6 \pm 2$	1150[n]	22	Nice et al. (2005)
J1012+5307	2.4 ± 0.2	–25.2 ± 0.2	840[o]	107	Lange et al. (2001)
J1045–4509	–5 ± 2	6 ± 1	1940[n]	119	Toscano et al. (1999a)
J1455–3330	5 ± 6	24 ±12	530[n]	71	Toscano et al. (1999a)
J1640+2224	1.66 ± 0.12	–11.3 ± 0.2	1160[n]	67	Löhmer et al. (2005)
J1643–1224	3 ± 1	–8 ± 5	2320[n]	96	Toscano et al. (1999a)
J1709+2313	–3.2 ± 0.7	–9.7 ± 0.9	1390[n]	57	Lewandowski et al. (2004)
J1713+0747	4.917 ± 0.004	–3.933 ± 0.010	1100[p]	30	Splaver et al. (2005)
B1855+09	–2.94 ± 0.04	–5.41 ± 0.06	910[p]	17	Kaspi, Taylor, & Ryba (1994)
J1909–3744	–9.6 ± 0.2	–35.6 ± 0.7	820[p]	131	Jacoby et al. (2003)
J1911–1114	–6 ± 4	–23 ±13	1220[n]	128	Toscano et al. (1999a)
B1953+29	–1.0 ± 0.3	–3.7 ± 0.3	4610[n]	128	Wolszczan et al. (2000b)
B1957+20	–16.0 ± 0.5	–25.8 ± 0.6	2490[n]	325	Arzoumanian et al. (1994)
J2019+2425	–9.41 ± 0.12	–20.60 ± 0.15	1490[n]	142	Nice, Splaver, & Stairs (2001)
J2051–0827	1 ± 2	–5 ± 3	1040[n]	42	Stappers et al. (1998)
J2129–5721	7 ± 2	–4 ± 3	1340[n]	48	Toscano et al. (1999a)
J2229+2643	1 ± 4	–17 ± 4	1440[n]	130	Wolszczan et al. (2000b)
J2317+1439	–1.7 ± 1.5	7.4 ± 3.1	820[n]	20	Camilo et al. (1996)

[p]Distance from parallax.
[n]DM distance from NE2001.
[o]Some other method used to acquire distance. The text of the cited reference should be consulted for details.

as they oscillate in the Galaxy's potential. Our determination that the two velocity distributions are in fact indistinguishable makes this scenario unlikely. However, with identical velocity distributions, a difference in intrinsic *luminosity* distributions would cause the less-luminous population to be detected only to smaller distances and hence only to smaller scale heights. In fact, Bailes et al. (1997) find that luminosities of isolated and binary MSPs are different at the 99.5% confidence level, with the isolated MSPs being intrinsically dimmer. We have confirmed their results with an updated catalog; also, a simple examination of the median distance of the isolated population (510 pc) compared to the median distance of the binary population (1155 pc) suggests that the isolated MSPs must be less luminous.

6. CORRECTIONS TO $\dot{P}$

Using our upper limit on the proper motion, we can calculate the upper limit of the Shklovskii correction to the period derivative $\dot{P}$. We find that 4.4×10^{-22} or not quite 5% of the measured $\dot{P}$ may be due to proper motion. The acceleration toward the disk of the Galaxy is about the same size in the other direction, -5.0×10^{-22}. The acceleration in the disk makes a much smaller contribution, -2.2×10^{-23}. Combining these corrections changes the measured $\dot{P}$ by less than 1%.

7. THE LOCAL INTERSTELLAR MEDIUM

The parallax measurement of 3.3 ± 0.9 mas yields a distance of 300 ± 90 pc. This falls in between the distance estimates made by the old (Taylor & Cordes 1993, hereafter TC93) and new (Cordes & Lazio 2002, hereafter NE2001) distance models: 230 and 317 respectively. Both estimates are based on a DM of $4.3328 \pm 0.00020\,\mathrm{cm}^{-3}$pc (Lommen et al. 2000). In the second galactic quadrant, between 90° and 180° galactic longitude, PSR J0030+0451 is the first pulsar with a measured parallax, so it provides an important check of the NE2001 model. In addition to a parameterized model of the LISM, the model adds a number of clumps and voids to the previous TC93 model, but nothing in the direction of PSR J0030+0451. The agreement of our distance with theirs suggests no significant clumps or voids exist along this LOS.

Nearby pulsars with known parallaxes are very useful for studying the LISM. Scintillation parameters measure density fluctuations and have been used to map out the LISM, but are unable to measure densities. The density measurements must come from parallax (Bhat, Gupta, & Rao 1998). These authors model the LISM explicitly as a low density bubble surrounded by a shell of much higher density fluctuations, but more pulsars with known distances are required to confirm the model. PSR J0030+0451 will therefore be a marvelous tool

for studying the LISM.

8. CONCLUSIONS

We have measured the parallax of PSR J0030+0451 to be 3.3 ± 0.5 mas. We have measured its proper motion to be -5.74 ± 0.09 mas yr^{-1} in the plane of the ecliptic and have established an upper limit on its motion out of the plane at 10 mas yr^{-1}. The is one of the lowest velocities measured for any pulsar and is noteworthy even within the relatively low-velocity millisecond pulsar population.

Combining proper motion data from this pulsar with the collection of existing MSP proper motion measurements, we find the statistical properties of the transverse velocities of isolated and binary MSPs are indistinguishable from each other. We do, however, find that the average z-height of the isolated MSPs is half that of the binary MSPs. We suggest that a luminosity difference between the two classes of objects, such as that suggested by Bailes et al. (1997), Kramer et al. (1998), and Hobbs et al. (2004), is the simplest way to account for both the observed difference in z-height and the similarity of the velocity distributions.

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